Report SFCG 30-1

SPECTRUM REQUIREMENTS FOR PLANNED SRS UPLINKS IN THE BAND 22.55 – 23.15 GHZ

ABSTRACT

This report presents the spectrum requirements needed for the proposed new SRS uplink allocation in the band 22.55-23.15 GHz. The general requirements are first enumerated and then specific requirements are shown for a number of space agencies. Conceptual frequency and channel plans are also developed and show that a minimum of 580 MHz would be needed to fulfil basic bandwidth requirements of several space agencies.

1. INTRODUCTION

To support the SRS missions in near Earth orbit, including missions in transit to the moon and at or near the moon, downlink (space-to-Earth) transmissions will operate in the 25.5-27.0 GHz band. This 1.5 GHz wide downlink band will be used for both scientific data retrieval and real time voice/video communication with the Earth.

An allocation to the space research service (Earth-to-space) to support lunar missions, Lagrangian missions and other near-Earth space research missions in the 22.55-23.15 GHz band is needed as a companion band to the existing 25.5-27.0 GHz SRS (space-to-Earth) allocation.

Resolution **753 (WRC-07)** recognizes that the band 22.55-23.55 GHz is allocated to the fixed, inter-satellite and mobile services, that those systems need to be protected and their future requirements be taken into account, and that non-GSO inter-satellite service links have been operating for several years and are expected to continue to operate in the 23.183-23.377 GHz band and that these links are increasingly being used in situations of emergencies and natural disaster.

Resolution **753 (WRC-07)** calls for sharing studies between space research service systems operating in the Earth-to-space direction and the fixed, inter-satellite and mobile services in the band 22.55-23.15 GHz. Appropriate sharing criteria for an allocation to the space research service in the Earth-to-space direction needs to be developed.

The number of SRS earth stations transmitting in the 22.55-23.15 GHz band will be small. Rather than building new SRS earth stations, upgrading selected existing SRS earth stations will predominate. Selecting which SRS earth stations to upgrade will be based on a number of factors, including the type of mission to be supported. The maximum number of SRS earth stations capable of supporting lunar and/or Lagrangian missions is not expected to exceed ten to fifteen on a global basis over the next few decades.

A similar number of additional SRS earth stations may support LEO missions with typically much lower e.i.r.p. density levels in view of the significantly lower orbital heights. These earth stations are typically located in rural, isolated areas at mid latitudes.

Annex 1 presents some additional details on the estimated data rate and spectrum requirements per agency.

2. GENERAL SPECTRUM REQUIREMENTS

The requested SRS allocation at 23 GHz is the natural companion band to the recently allocated SRS downlink at 26 GHz and would meet this long term objective, enabling space agencies to plan with some certainty their longer term space exploration national strategic objectives. Both manned and robotic missions are planned with participation from many governments as well as the private sector. Due to the potential for many concurrent exploration or related systems and the large bandwidth requirements of these systems, especially those supporting manned missions, it is estimated that a combined uplink bandwidth of 600 MHz will be needed as a minimum, taking into account the projected mission support activities by several space agencies throughout the world. The bandwidth requirement is based on exclusive use of channels due to antenna beamwidth overlap, synergistic operations with existing data relay systems, selection of frequencies due to ranging constraints, and the evolution, growth, and complexity of those systems over a period of 20-30 years.

While an allocation in the range 22.55 – 23.15 GHz is necessary as a complementary uplink to the 25.5 – 27.0 GHz band, its utilization in an unbroken, contiguous format of sufficiently large bandwidth will be necessary for the following reasons. Frequency re-use is unlikely due to operational constraints since any spacecraft around the moon will be in the antenna main-beam lobe of other space agencies supporting their own lunar missions. Space agencies require their own segments of spectrum for lunar and many Lagrangian missions since antenna discrimination is not possible. Despite large earth station antennas, the moon is fully within the main lobe of such antennas. In addition, the frequencies to be selected will need to be aligned with the internationally agreed channels for data relay systems in order to provide global support either via an Earth station or via a data relay satellite. These data relay channels have a specific spacing of 60 MHz for interoperability among space agencies' data relay systems, which can support a range of data rates up to 50 Mb/sec. Furthermore, depending on the location of the Earth stations, some frequency sub-bands are not available due to operations of other services in the vicinity, such as the fixed service and/or the radio astronomy service.

Finally, there is a planned fixed turn-around ratio required between the Earth-to-space link around 23 GHz and the corresponding space-to-Earth link in the 25.5-27 GHz band. This is required for ranging purposes, and access to portions of the 26 GHz space-to-Earth allocation may not always be possible due to the presence of pre-existing assignments to co-primary services in the SRS earth station vicinity. The latter assignments constraints would further limit, in some geographic locations, the choice of available companion frequencies in the uplink band at 23 GHz. Also, pre-existing assignments in the 23 GHz band will similarly preclude unconstrained access in some regions.

Space exploration programs demand ambitious technical evolution, with development and implementation constantly being subject to shifts in architecture. To this end the near-Earth region as well as the lunar region will need to be used as in-situ test beds for evaluating candidate hardware and software systems and concepts. This will lead to real time uplink operational control and will further increase high uplink bandwidth requirements. Proposals from a number of Administrations to WRC-07 supporting the objectives of the Space Frequency Coordination Group (SFCG) for this agenda item, originally sought the entire band 22.55 – 23.55 GHz. However, following consideration of co-frequency compatibility concerns expressed at WRC-07 with respect to the existing HIBLEO-2 system that operates above 23.18 GHz, the space research service community, in a spirit of good will and to avoid frequency overlap with HIBLEO-2, agreed to limit the bandwidth under consideration to 600 MHz.

3. SPECIFIC SPECTRUM REQUIREMENTS

Based on international coordination at SFCG meetings as well as in other fora, it is envisaged that at least six space agencies will operate lunar and Lagrangian links over the next few decades. As representative examples of future lunar mission scenarios, one 24 MHz carrier and three 12 MHz carriers have been assumed for each of six space agencies' missions . The 24 MHz channels have to be centred on the DRS cross support centre frequencies. The resulting spectral gaps may be used for additional narrow band channels not taken into account in this minimum set of requirements. Each lunar link has envisioned a 5 MHz guard band which may vary depending on the data rate of the individual channel. It is also assumed that these six agencies will operate at least one single Lagrangian link with 3 MHz bandwidth and a 1 MHz guard band. Actually applied bandwidths may vary to some extent depending on the requirements of individual space agencies.

Table 1 and Figure 1 show the bands that have been used for this example. It can be seen that the total bandwidth required is 580 MHz. The following have been implicitly assumed:

- Co-frequency sharing between lunar or Lagrangian missions on the one hand and LEO or DRS missions on the other hand will be possible.
- Co-frequency sharing between lunar or Lagrangian missions and radio astronomy service (RAS) missions will be possible but could reduce the flexibility in some locations of assigning channels for SRS ground stations nearby RAS sites.
- Co-frequency sharing among lunar missions, among Lagrangian missions, and between lunar missions and Lagrangian missions is not possible.
- The frequency plan is compatible with 60 MHz DRS channel spacing plans: each 24 MHz lunar carrier's center frequency is placed at one of these frequencies. Specifically, the following frequencies are used: 23 085, 23 025, 22 965, 22 905, 22 845, 22 785 MHz.
- The first 12 MHz lunar carrier is placed at the upper edge of the 22 550-23 150 MHz band, and the other 12 MHz carriers are placed on lower frequency adjacent channels, each having a 5 MHz guard band, and also avoid the 24 MHz Lunar carriers.

- The first 3 MHz Lagrangian carrier is placed 5 MHz lower than the final 12 MHz lunar carrier, and the other 3 MHz carriers are placed on lower frequency adjacent channels, each having a 1 MHz guard band

The actual placement of carriers may be more complex, because it has been assumed that the frequency plan is compatible with planned fixed turn-around ratio required between the Earth-to-space link around 23 GHz and the corresponding space-to-Earth link in the 25.5-27 GHz band.

4. CONCLUSION

A study of bandwidth requirements of several space agencies shows that a minimum of 580 MHz would be needed, and that even this bandwidth is a conservative estimate, as several simplifying assumptions are made in developing this conceptual plan.

Agency	Orbit	Lower Freq (MHz)	Upper Freq (MHz)
NASA	Lunar	23073	23097
		23138	23150
		23121	23133
		23104	23116
JAXA	Lunar	23013	23037
		23056	23068
		22996	23008
		22936	22948
RFSA	Lunar	22953	22977
		22876	22888
		22816	22828
		22756	22768
ISRO	Lunar	22893	22917
		22739	22751
		22722	22734
		22705	22717
CNSA	Lunar	22833	22857
		22688	22700
		22671	22683
		22654	22666
ESA	Lunar	22773	22797
		22637	22649
		22620	22632
		22603	22615
NASA	L2	22595	22598
JAXA	L2	22590	22593
RFSA	L2	22585	22588
ISRO	L2	22580	22583
CNSA	L2	22575	22578
ESA	L2	22570	22573

Table 1: Conceptual Frequency Plan

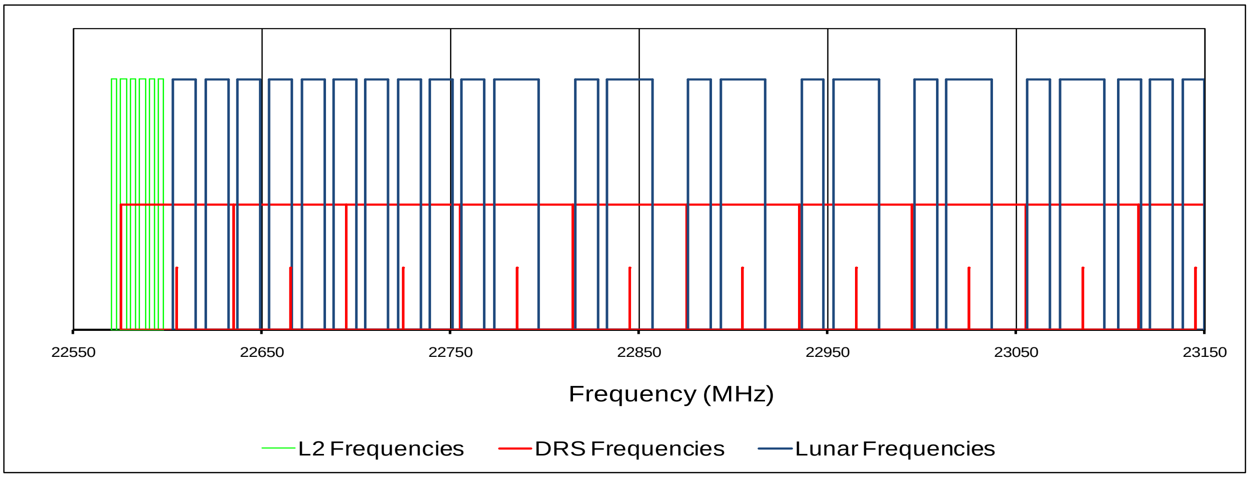


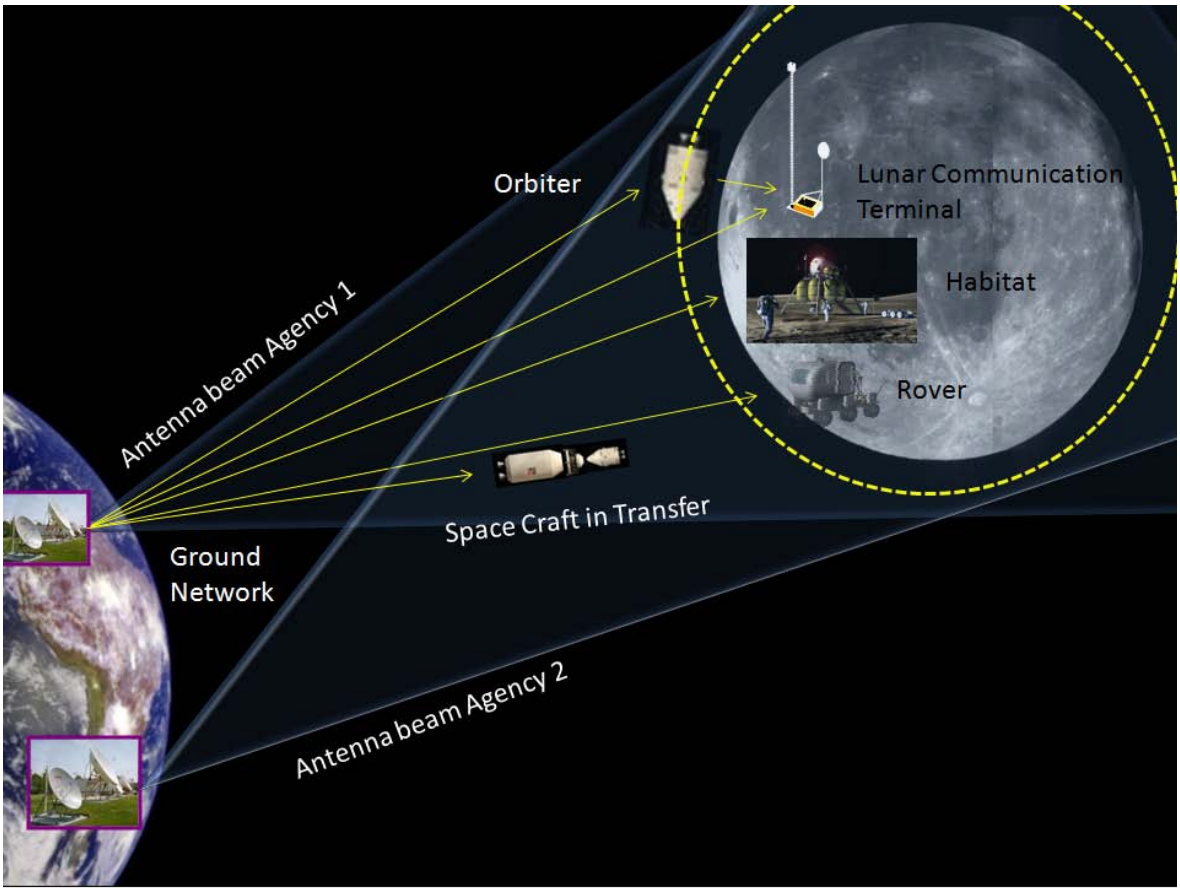
Figure 1: Conceptual Channel Plan

Annex 1: Estimated Data Rate and Spectrum Requirements per Agency

Over the past couple of years, multiple orbiting and impactor spacecrafts from several agencies have been sent to the Moon with missions to obtain high resolution lunar terrain maps, ascertain chemical composition of the Moon's surface, examine lunar soil layers and probe/record the environment on the Moon, such as its electromagnetic features and solar wind, which are crucial for future landings. These precursor missions are integral steps in the lunar exploration roadmaps for these agencies. These planned robotics and manned missions include a variety of spacecraft/vehicles on the lunar surface and orbits such as orbiters, landers, experiment packages/terminals, rovers, robotic assistants, extravehicular activities (EVAs), communications terminals, and relay satellites.

The frequency plan for the lunar region will revolve around communications from Earth to the lunar region, lunar region to Earth, lunar surface to orbit communications, lunar communications between several points on the surface, and lunar orbit to lunar orbit communications. Multiple simultaneous communications links are expected to operate in the vicinity of the Moon to control/command equipment operation, communicate with on-orbit crew, stream video, update/modify/verify software uploads, enable health diagnosis, execute detailed fault detection/isolation/recovery procedures and adjust mission plans based on science and telemetry data with precise and high resolution instructions and graphics. Figure A-1 provides an overview of the types of links typically supported simultaneously via an earth station.

Figure A-1: A conceptual scenario representing space agency lunar orbit and surface communication elements



These links will mainly be used for a wide range of bandwidth intensive applications, such as video and data transmissions. Some of the links to the surface of the moon can be a multiplex of several applications which are described in Table A-1. For the modulation techniques, filtered QPSK has been assumed. Regarding channel coding, coding rates vary between 1/2 and 7/8, depending on the specific mission application.

Link Type	Usage Description	Users	Estimated Symbol Rates (per User)	Estimated BW (per User)
Earth to Lunar Orbit	Direct high rate communications from the Mission Control Center (through an earth station) to orbiter in low lunar orbit. Contents of link include composite/multiplex data stream such as spacecraft system management controls, software maintenance updates, data encryption/authentication protocol, network security protocol, detail mission plans/instructions, in-flight maintenance procedures, voice with onboard crew, navigation updates, video conferencing and streaming video.	Orbiter/ Manned & Unmanned	10-20 MSps	10 - 20 MHz
Earth to Lunar Surface	Direct high rate communications from both the Mission Control Center and Payload Control Center (through an earth station) to communications terminal on lunar surface for re-distribution to both mobile and fixed elements on the surface of the Moon.The communications terminal serves as a “cell tower” to relay mission & system updates to multiple surface experiments and interactive capability for individual Principle Investigators with experiments they are responsible. Contents of link include experiment system management controls, software maintenance updates, data encryption/authentication protocol, network security protocol, detail mission plans/instructions, high fidelity/resolution maps, etc.	Communications Terminal/ Manned & Unmanned	20-25 MSps	20-25 MHz
Earth to Lunar Surface	Direct high rate communications from the Mission Control Center (through an earth station) to the lunar Surface Habitat. Contents of link include composite/multiplex data streams such as Habitat system management controls, Habitat software maintenance updates, data encryption/authentication protocol, network security protocol, detail mission plans/instructions, in-flight maintenance procedures, voice with crew, video conferencing and streaming video.	Habitat/ Manned	10-20 MSps	10-20 MHz
Earth to Lunar Surface	Direct high rate communications from the Mission Control Center (through an earth station) to rovers or landers on the lunar surface. Contents of link include spacecraft system management controls, detailed mission plan updates/revisions, software maintenance updates, data encryption/authentication protocol, network security protocol, high fidelity/resolution maps, video instructions, direct voice with MCC to Extra Vehicular Activity (EVA) astronauts.	Rovers/ Landers/ Manned & Unmanned	10-20 MSps	10-20 MHz
Earth to Transfer Spacecraft	Direct high rate communications from the earth station to the transfer spacecraft. Contents of link include composite/multiplex data stream such as spacecraft system management controls, software maintenance updates, detail mission plans/instructions, in-flight maintenance procedures, voice with onboard crew, navigation updates, video conferencing and streaming video.	Spacecraft Manned & Unmanned	10-25 MSps	10-25 MHz

Table A-1: Communications Requirements Matrix

Figure A-2 shows a conceptual scenario of Earth-to-lunar surface links.

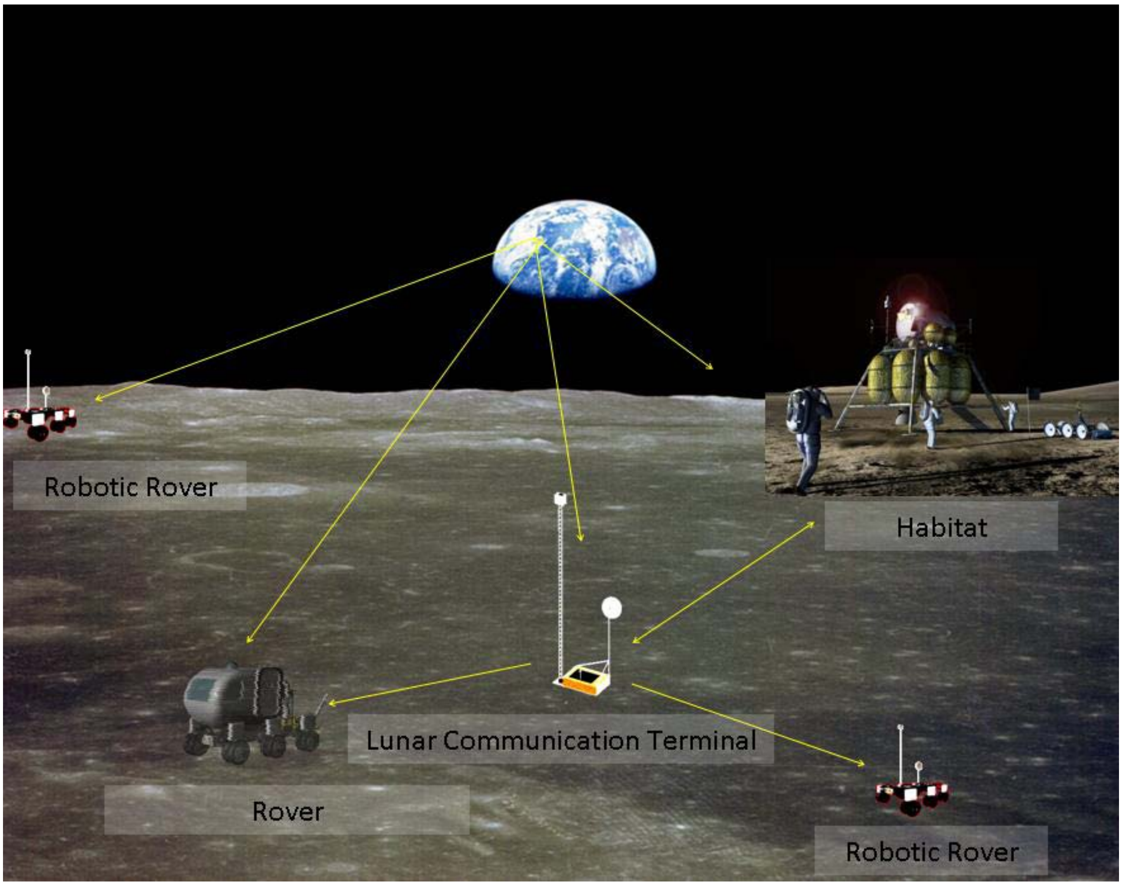


Figure A-2: A conceptual scenario representing Earth-to-Lunar Surface Communication Elements

Each agency can operate lunar missions with multiple carriers of the nature discussed above, and potentially anywhere on the surface of the Moon. The interference caused by the intersection of their respective beams would preclude co-frequency sharing among lunar missions. The same holds true for co-frequency operations of Lagrangian missions.

Additionally, co-frequency sharing between lunar and Lagrangian missions' carriers from separate earth stations is also not possible, as the geometry discussed above results in small off-axis angles between carriers.

However, co-frequency sharing is possible between other combinations of carriers. The specific compatibility of these various scenarios is shown in Table A-2.

Interf/Victim	Lunar	Lagrangian	LEO	DRS
Lunar	N	N	Y	Y
Lagrangian	N	N	Y	Y
LEO	Y	Y	Y	Y
DRS	Y	Y	Y	Y

Table A-2: Compatibility Matrix for SRS Mission Types

It should be noted that these 23 GHz links in support of LEO missions, will not be able to be used in the same manner as links in the 7 GHz band due to increased atmospheric attenuation and other physical constraints effecting in particular omni-directional antenna design.

There is a need for a guard band between each channel, since, due to the in-beam geometry and significant spectral densities of near side lobes, some out-of-band roll-off attenuation is required. Using Recommendation SM.1541, for the 12 MHz lunar links a 5 MHz guard band results in out-of-band attenuation of 12.5 dB, and for the 3 MHz Lagrangian links a 1 MHz guard band results in out-of-band attenuation of 10.0 dB. Achieving an attenuation of 12.5 dB for a 24 MHz channel will require a guard band of around 10 MHz. Depending on the actual channel bandwidths, guard bands between 1 and 10 MHz are therefore expected to be required.